

BLOOD PARASITES OF RAPTORS IN FLORIDA

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ABSTRACT.—Fifteen species of blood protozoans and an unidentified microfilaria were found in thin blood films from 55 strigiforms and 138 falconiforms examined in Florida. All four of the species of strigiforms sampled were infected, with an overall hemoparasite prevalence of 63%, excluding nestlings. Seven of 11 species of falconiforms sampled were parasitized, with a prevalence of 33%, excluding nestlings. Mixed infections of two or more species occurred in 28 birds, 22 had two species of hemoparasites, three had three species, and three had four species. Among the infections of hemoparasites, *Haemoproteus* species were most common (67%), followed by *Plasmodium* (22%), *Leucocytozoon* (9%), *Trypanosoma* (1%), and microfilariae (1%). A *Plasmodium* (*Novyella*) sp., previously known only from a barred owl (*Strix varia*) in Georgia, was present in the great horned owl (*Bubo virginianus*), bald eagle (*Haliaeetus leucocephalus*), and broad-winged hawk (*Buteo platypterus*) in Florida. The identification of *Leucocytozoon ziemanni* is the first record of this species in barn owls (*Tyto alba*) from North America and *Trypanosoma confusum* is reported for the first time in a barred owl.

KEY WORDS: *Falconiformes*; *Florida*; *hemoparasites*; *prevalence*; *raptors*; *Strigiformes*.

Parásitos sanguíneos de rapaces en Florida

RESUMEN.—Quince especies de protozoos sanguíneos y una “microfilaria” fueron encontrados en delgados frotis de sangre obtenidos en 55 Strigiformes y 138 Falconiformes de Florida. Las cuatro especies de Strigiformes muestreadas estaban infectadas con una prevalencia del 63% de hemoparásitos, excluidos los polluelos. Siete de 11 especies de Falconiformes muestreados estaban parasitados con una prevalencia del 33%, excluidos los pollos. Infecciones mezcladas de dos o más especies afectaron a 28 aves, tres tenían cuatro especies de parásitos. Entre las infecciones por hemoparásitos, *Haemoproteus* fue la especie más común (67%), seguido de *Plasmodium* (22%), *Leucocytozoon* (9%), *Trypanosoma* (1%) y microfilariae (1%). *Plasmodium* (*Novyella*) sp., previamente conocido sólo para *Strix varia* en Georgia, estaba presente en *Bubo virginianus*, *Haliaeetus leucocephalus* y en *Buteo platypterus* en Florida. La identificación de *Leucocytozoon ziemanni*, es el primer registro de esta especie en *Tyto alba* presente en América del Norte. *Trypanosoma confusum* es reportado por primera vez en *Strix varia*.

[Traducción de Ivan Lazo]

Strigiforms and falconiforms are prominent components of the avifauna of Florida, yet their blood parasites are poorly known. We are aware of only three publications dealing with this topic in Florida. Greiner et al. (1981) reported a parasite resembling *Plasmodium polare* in a bald eagle (*Haliaeetus leucocephalus*); Sykes and Forrester (1983) examined blood films from 19 snail kites (*Rostrhamus sociabilis*) without finding hemoparasites; and Dooris et al. (1981) found no blood parasites in 30 burrowing owls (*Speotyto cunicularia*).

The objectives of the present study were to determine the species and prevalence of blood parasites present in raptors in Florida, and to compare these

data with information on parasite infections of raptors from other geographic areas. Some host records in the present paper have been included also in a brief and limited format in a host-parasite catalogue (Bishop and Bennett 1992) and in a taxonomic review of the haemoproteids of falconiforms (Peirce et al. 1990).

METHODS

We obtained blood films from 55 strigiforms (four species) and 138 falconiforms (11 species) from 1973–91. All birds sampled were fledged juveniles or adults with the exception of 44 bald eagles and one eastern screech-owl (*Otus asio*) which were nestlings (<8 wk of age). Exact ages were not known. Of the 147 fledged raptors for which

we have precise locality information (the locality was unknown for one eagle), 121 were from northern Florida (localities north of Manatee, Polk, Osceola, and Brevard counties) and 26 were from southern Florida (localities south of the above listed counties).

Thin blood smears were prepared from cardiac or peripheral blood, fixed in absolute methanol, and stained by standard Giemsa technique for 1 hr at pH 7.0, or in the case of fixed but unstained slides which had been stored for several months, by Giemsa in an acidic acetone-based buffer at pH 6.4 for 1.5–2 hr (Kimsey 1992). Material obtained from the College of Veterinary Medicine, University of Florida, was comprised of coverslip smears that had been stained by the Wright-Giemsa method. Slides were examined at 400 \times to determine prevalences of parasites. Measurements of parasites were done with a calibrated ocular micrometer under oil immersion (1000 \times). The taxonomic characters used for identification of parasites were those utilized by Telford (1988) for *Plasmodium* species, by Forrester et al. (1977), Bennett and Peirce (1988), Peirce et al. (1990), and Bishop and Bennett (1989) for *Haemoproteus* species, by Greiner and Kocan (1977) and Bennett et al. (1991) for *Leucocytozoon* species, and by Baker (1976) and Telford et al. (1991) for trypanosomes. Statistical comparisons of sample means were made by Student's *t*-test, and of sample proportions by chi-square ($\alpha = 0.05$).

Representative blood films have been deposited in the collection of the International Reference Centre for Avian Haematozoa, Memorial University, St. John's, Newfoundland (Accession Nos. 68665, 116415–116441, and 125553–125556).

RESULTS

Hemoparasites were found in all species of raptors examined except the black vulture (*Coragyps atratus*), turkey vulture (*Cathartes aura*), osprey (*Pandion haliaetus*), and merlin (*Falco columbarius*) (Table 1). The 44 nestling bald eagles and the one nestling eastern screech-owl were negative and were not included in statistical analyses or comparisons because of their young age and because nestlings were not included in the samples of other species. Overall, strigiforms showed a significantly greater prevalence of hemoparasites than did falconiforms (63 vs. 33%, chi-square, $P < 0.01$).

Haemoproteus species were most common (67%), followed by *Plasmodium* (22%), *Leucocytozoon* (9%), *Trypanosoma* (1%), and microfilariae (1%). Fifty-eight infections were found in strigiforms: 44 *Haemoproteus* (76%), 11 *Plasmodium* (19%), one *Leucocytozoon* (2%), one *Trypanosoma* (2%), and one microfilarial infection (2%). There were 43 infections in falconiforms: 25 *Haemoproteus* (58%), 11 *Plasmodium* (26%), and seven *Leucocytozoon* (16%), but no trypanosomes or microfilariae. Mixed infections of two or more species occurred in 28 birds:

22 had two species, three had three species, and three had four species.

An apparently undescribed *Plasmodium* (*Novyella*) species was seen in three birds: a great horned owl (*Bubo virginianus*), a bald eagle, and a broad-winged hawk (*Buteo platypterus*). Gametocytes of this parasite had notably crenulate margins. Schizonts were tiny with four nuclei, were fan-shaped or cruciform, measured 3.5–4.5 \times 2–4 μ m and were found in mature erythrocytes.

DISCUSSION

The same *Plasmodium* (*Novyella*) species reported from a barred owl (*Strix varia*) from southern Georgia by Telford and Forrester (1992) is reported here from three additional hosts. The characteristic schizonts were common in the great horned owl, very rare in the bald eagle, and absent in the broad-winged hawk. Identification of the infection in the latter host was based upon a high proportion of gametocytes which had irregular or crenulate margins.

Greiner et al. (1981) reported the presence of distinctive gametocytes with crenulate margins in a bald eagle infected by parasites resembling *P. polare*, but were uncertain whether they represented a separate taxon or were possibly senescent. We were able to study blood films from the bald eagle examined by Greiner et al. (1981). The gametocytes with crenulate margins were the most common form present in a ratio to those of *P. polare* that exceeded 50:1, which would argue against senescence. Discovery of a few tiny schizonts similar to those found in the barred owl from Georgia (Telford and Forrester 1992) and the great horned owl (this paper) provided additional evidence of their conspecificity with this undescribed species. These probably are not immature schizonts of *P. polare* because in this species, nuclear division does not begin until the trophozoites are nearly twice the size of the *Plasmodium* (*Novyella*) sp. schizonts. The identification of *P. polare*-like parasites in the bald eagle by Greiner et al. (1981) is appropriate, given the paucity of data available for this species of *Plasmodium*.

We have identified the haemoproteid from eastern screech-owls as *H. syrni*, but it is possible that it represents another, possibly undescribed species. Gametocytes in screech-owls were smaller and less heavily pigmented than those of *H. syrni* in barred owls and great horned owls. These variations may have been due to strain differences or host effects, but further studies are needed. Both *H. syrni* and

Table 1. Occurrence of blood parasites in fledged raptors from Florida, 1973-91.

TAXON	NUMBER OF BIRDS		NUMBER OF BIRDS INFECTED WITH ^a																
	EXAM- INED	IN- FECTED	HE	HNI	HNO	Hs	Ht	Hs	HT	PC	PE	PN	PP	PR	PS	LT	LZ	Tc	MF
Strigiformes																			
<i>Tyto alba</i>	4	3															1 ^b		1
<i>Bubo virginianus</i>	10	8			4	6				1	1			1					
<i>Otus asio</i>	12	5				4				1					1				
<i>Strix varia</i>	28	19			11	19			1	1				1					1 ^c
Falconiformes																			
<i>Accipiter cooperii</i>	6	1								1						1			
<i>A. striatus</i>	11	1								1						1			
<i>Buteo jamaicensis</i>	14	7		1						4						1			
<i>Buteo lineatus</i>	22	10												1		1			
<i>Buteo platypterus</i>	3	2													1				
<i>Haliaeetus leucocephalus</i>	23	8								2	1					4			
<i>Cathartes aura</i>	3	0																	
<i>Coragyps atratus</i>	2	0																	
<i>Falco columbarius</i>	1	0																	
<i>F. sparverius</i>	3	2													2				
<i>Pandion haliaetus</i>	6	0																	
Total	148	66	20	2	15	29	2	2	1	10	3	1	1	3	1	8	1	1	1

^a He = *Haemoproteus elani*, Hni = *H. nisi*, Hno = *H. noctuae*, Hs = *H. sylvii*, Ht = *H. tinnunculi*, Pc = *Plasmodium circumflexum*, Pe = *P. elongatum*, Pp = *P. polare*, Pr = *P. relictum*, Ps = *P. subpraecox*, Pn = *P. (Noeyella) sp.*, Lt = *Leucocytozoon toddi*, LZ = *L. ziemanni*, Tc = *Trypanosoma confusum*, MF = microflariae.

^b New North American record.

^c New host record.

Table 2. Prevalences of the common genera of blood parasites in raptors from North America and the Neotropical region.

	NUMBER OF BIRDS EXAMINED	PER- CENT POSI- TIVE	PERCENT POSITIVE FOR				SOURCE
			Pa	H ^b	L ^c	T ^d	
Strigiformes							
North America	118	51	7	21	37	3	Greiner et al. (1975)
Maryland-New Jersey	28	18	4	7	7	4	Williams and Bennett (1978)
Florida	54	63	17	56	2	2	This study
Louisiana	34	68	0	73	12	0	Olsen and Gaunt (1985)
Neotropics	44	25	9	18	+ ^e	+ ^e	White et al. (1978)
Falconiformes							
North America	309	40	3	23	21	3	Greiner et al. (1975)
Maryland-New Jersey	33	33	0	33	9	0	Williams and Bennett (1978)
New Jersey area ^f	249	59	1	22	43	1	Kirkpatrick and Lauer (1985)
Florida	93	33	11	26	8	0	This study
Louisiana	21	24	0	14	9	0	Olsen and Gaunt (1985)
Neotropics	119	30	8	19	1	2	White et al. (1978)

^a *Plasmodium*.^b *Haemoproteus*.^c *Leucocytozoon*.^d *Trypanosoma*.^e Prevalences not given by author.^f New Jersey, Pennsylvania, Delaware, and Virginia.

H. noctuae have been reported previously from eastern screech-owls (Bishop and Bennett 1989).

Trypanosoma confusum is known from several strigiforms (Bennett et al. 1982, Bishop and Bennett 1992), but has not been reported previously from the barred owl. An unidentified trypanosome found by Wetmore (1941) in the barred owl was probably *T. confusum*. Although Baker (1976) has defined the trypanosome from the New World as *T. confusum*, the parasite is morphologically indistinguishable from *Trypanosoma avium* of Old World strigids. Bennett (1961, 1970) showed that the trypanosome originating from the northern saw-whet owl (*Aegolius acadicus*) could be transmitted via the mosquito *Aedes aegypti* to a number of different avian species of several orders and families, thus indicating a total lack of host specificity. Measurements and derived indices from trypanosomes from Old and New World boreal owls (*Aegolius funereus*) are identical to those from the northern saw-whet owl and the two species of trypanosomes are likely to be synonymous (G. Bennett unpubl. data).

Falconiforms were parasitized more commonly by *Leucocytozoon* than were strigiforms. This may reflect a greater opportunity for contact with the si-

multiid vectors by falconiforms because of their broader ranges, in comparison to the more sedentary strigiforms. It is possible also that strigiform behavior patterns (foraging at night and using secluded, shady perches during day) expose them more frequently to a variety of vector species (and hence a larger variety of hemoparasites) than do those of falconiforms (daytime activity period and elevated perches at night).

The overall prevalence of *Plasmodium* species in both strigiforms and falconiforms in Florida was greater than that recorded in other comparable surveys (Table 2). These prevalences probably would have been even higher if isodiagnostic techniques had been used since *Plasmodium* infections in birds are known to virtually disappear from the circulating blood when infections become chronic (Herman et al. 1966). *Haemoproteus* species were also more common in strigiforms in Florida than in other areas except Louisiana (Olsen and Gaunt 1985), but in falconiforms their prevalence in Florida was similar to the overall estimate for North America (Greiner et al. 1975) and the Neotropics (White et al. 1978). *Leucocytozoon* species, however, had a lower prevalence in strigiforms from Florida than generally in

North America (Greiner et al. 1975) or on the eastern seaboard (Williams and Bennett 1978). In falconiforms, *Leucocytozoon* species had a lower prevalence in Florida than reported in the North American survey (Greiner et al. 1975) and the 1985 New Jersey survey (Kirkpatrick and Lauer 1985), but was comparable to that found in the 1978 Maryland-New Jersey survey (Williams and Bennett 1978) and the Louisiana survey (Olsen and Gaunt 1985). *Leucocytozoon* species are present in the Neotropics (White et al. 1978), but there is little information on prevalences. The data on *Trypanosoma* from all areas surveyed may be misleading because of the inefficiency in detecting infections by using blood films; more trypanosome infections would have been detected if bone marrow had been examined and if culture methods had been used.

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LITERATURE CITED

- BAKER, J.R. 1976. Biology of the trypanosomes of birds. Pages 131-174 in W.H.R. Lumsden and D.A. Evans [EDS.], *Biology of the Kinetoplastida*. Vol. 1. Academic Press, New York, NY U.S.A.
- BENNETT, G.F. 1961. On the specificity and transmission of some avian trypanosomes. *Can. J. Zool.* 39:17-33.
- . 1970. *Trypanosoma avium* Danilewsky in the avian host. *Can. J. Zool.* 48:803-807.
- AND M.A. PEIRCE. 1988. Morphological form in the avian Haemoproteidae and an annotated checklist of the genus *Haemoproteus* Kruse, 1890. *J. Nat. Hist.* 22:1683-1696.
- , M. WHITEWAY AND C. WOODWORTH-LYNAS 1982. A host-parasite catalogue of the avian haematozoa. *Mem. Univ. Newfoundland Occ. Pap. Biol.* 5, St. John's, Newfoundland, Canada.
- , R.A. EARLE, M.A. PEIRCE, F.W. HUCHZERMAYER AND D. SQUIRES-PARSONS. 1991. Avian Leucocytozoidae: the leucocytozoids of the Phasianidae *sensu lato*. *J. Nat. Hist.* 25:1407-1428.
- BISHOP, M.A. AND G.F. BENNETT. 1989. The haemoproteids of the avian order Strigiformes. *Can. J. Zool.* 67:2676-2684.
- AND ———. 1992. Host-parasite catalogue of the avian haematozoa, Supplement 1 and bibliography of the avian blood-inhabiting haematozoa, Supplement 2. *Mem. Univ. Newfoundland Occ. Pap. Biol.* 15, St. John's, Newfoundland, Canada.
- DOORIS, G.M., P.M. DOORIS AND W.D. COURSER. 1981. The absence of hematozoa in burrowing owls of the Tampa Bay area, Florida. *Fla. Field Nat.* 9:9.
- FORRESTER, D.J., E.C. GREINER, G.F. BENNETT AND M.K. KIGAYE. 1977. Avian Haemoproteidae. 7. A review of the haemoproteids of the family Ciconiidae (storks) and descriptions of *Haemoproteus brodkorbi* sp. nov. and *H. peircei* sp. nov. *Can. J. Zool.* 55:1268-1274.
- GREINER, E.C. AND A.A. KOCAN. 1977. *Leucocytozoon* (Haemosporidia; Leucocytozoidae) of the Falconiformes. *Can. J. Zool.* 55:761-770.
- , D.J. BLACK AND W.O. IVERSON. 1981. *Plasmodium* in a bald eagle (*Haliaeetus leucocephalus*) in Florida. *J. Wildl. Dis.* 17:555-558.
- , G.F. BENNETT, E.M. WHITE AND R.F. COOMBS 1975. Distribution of the avian hematozoa of North America. *Can. J. Zool.* 53:1762-1787.
- HERMAN, C.M., J.O. KNISLEY AND E.L. SNYDER. 1966. Subinoculation as a technique in the diagnosis of avian *Plasmodium*. *Avian Dis.* 10:541-547.
- KIMSEY, R.B. 1992. Host association and the capacity of sand flies as vectors of lizard malaria. *Int. J. Parasitol.* 22:657-664.
- KIRKPATRICK, C.E. AND D.M. LAUER. 1985. Hematozoa of raptors from southern New Jersey and adjacent areas. *J. Wildl. Dis.* 21:1-6.
- OLSEN, G.H. AND S.D. GAUNT. 1985. Effect of hemoprotozoal infections on rehabilitation of wild raptors. *J. Am. Vet. Med. Assoc.* 187:1204-1205.
- PEIRCE, M.A., G.F. BENNETT AND M. BISHOP. 1990. The haemoproteids of the avian order Falconiformes. *J. Nat. Hist.* 24:1091-1100.
- SYKES, P.W., JR. AND D.J. FORRESTER. 1983. Parasites of the snail kite in Florida and summary of those reported for the species. *Fla. Field Nat.* 11:111-116.
- TELFORD, S.R., JR. 1988. A contribution to the systematics of the reptilian malaria parasites, family Plas-

- modiidae (Apicomplexa: Haemospororina). *Bull. Fla. State Mus. Biol. Sci.* 34:65-96.
- AND D.J. FORRESTER. 1992. Morphometric comparisons of the *Plasmodium* (*Novyella*) species reported from North American birds, with comments on a species from the barred owl (*Strix varia* Barton). *System. Parasitol.* 22:17-24.
- , M.G. SPALDING AND D.J. FORRESTER. 1991. Hemoparasites of wading birds (Ciconiiformes) in Florida. *Can. J. Zool.* 70:1397-1408.
- WETMORE, P.W. 1941. Blood parasites of birds of the District of Columbia and Patuxent Research Refuge vicinity. *J. Parasitol.* 27:379-393.
- WHITE, E.M., E.C. GREINER, G.F. BENNETT AND C.M. HERMAN. 1978. Distribution of the hematozoa of neotropical birds. *Rev. Biol. Trop.* 26:43-102.
- WILLIAMS, N.A. AND G.F. BENNETT. 1978. Hematozoa of some birds of New Jersey and Maryland. *Can. J. Zool.* 56:596-603.

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